



NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 15-95

EVALUATION OF RIX 4VX AIR/NITROX COMPRESSOR

GEORGE D. SULLIVAN

NAVY EXPERIMENTAL DIVING UNIT

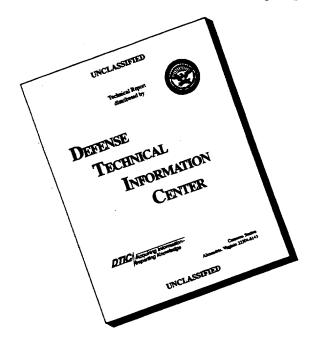


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EVALUATION OF RIX 4VX AIR/NITROX COMPRESSOR

GEORGE D. SULLIVAN December 1995

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I. INTRODUCTION

In response to NAVSEA tasking¹, Navy Experimental Diving Unit (NEDU) evaluated a RIX 4VX AIR/NITROX COMPRESSOR, MODEL 4VX4B-23.3B.² The test took place at NEDU from 25 October through 27 November 1995. The purpose was to:

- A. Determine if the compressor system provides compressed air at the required pressures, flow rates, quality and cleanliness required by the U.S. Navy³.
- B. Determine the adequacy of the manufacturer's information, instructions and guidance for the safe operation and overall management of the compressor.
- C. Ensure that the compressor system discharged clean breathing air required by the U.S. Navy³.

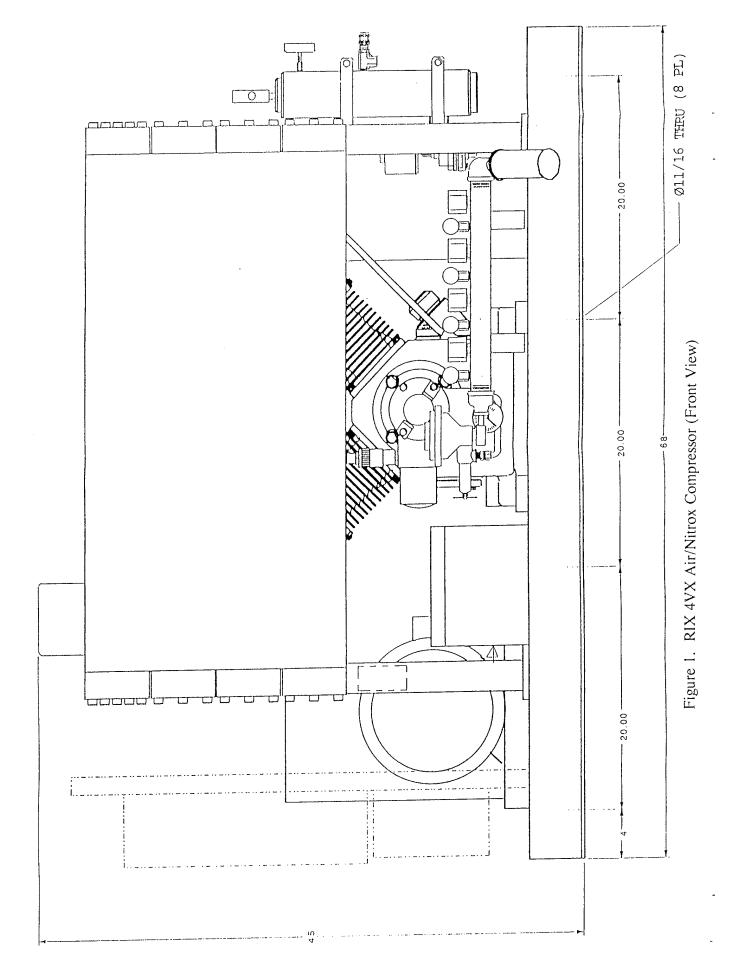
II. EQUIPMENT DESCRIPTION

The RIX 4VX AIR/NITROX COMPRESSOR, MODEL 4VX4B-23.3B is built in a four stage, four cylinder, "vee" configuration. The reciprocating, single acting, crosshead design features oil free operation through the use of self-lubricating piston rings constructed of TFE materials operating inside stainless steel cylinder bores. It is powered by a 25 HP, 3 Phase, electric motor (rated at either 208/380V, 50Hz, 3000 RPM or 230/460V, 60 Hz 3600 RPM) through a V-belt drive. All four stages feature oil-free compression which allows compression of nitrogen-oxygen mixtures of up to 40 percent oxygen to 5000 psig and compression of air to 5000 psig. Oil free compression eliminates the need for an elaborate purification system. The crank case components are oil pressure fed and the crank case is isolated from the cylinders by an enclosed vented void area.

The RIX compressor unit consists of a compressor block and a drive motor, both mounted on a slide base to provide a means of adjusting the drive belts (Figure 1 and 2). The drive unit for this test was a 460 Volt motor operating at 3600 RPM. Rotational torque is transferred to the compressor by a single banded-belt. Electric motors purchased for use with this compressor must comply with Navy standards for sealed insulated systems⁴.

Moisture separators (water traps) remove water after each stage (see Figure 3.) A cam timer actuates solenoid valves, which automatically drain the separators every fifteen minutes. The cam timer is manually adjustable and is located beneath the heat exchangers in the junction box mounted to the bedplate.

The compressor is air cooled by a 3/4 HP, hazardous duty design, electrically driven fan. Four finned tube heat exchangers cool the gas after compression in each successive stage. The cooling air is pulled through the heat exchangers by the fan, then split into separate streams and directed over the cooling fins of each cylinder head and compression cylinder.



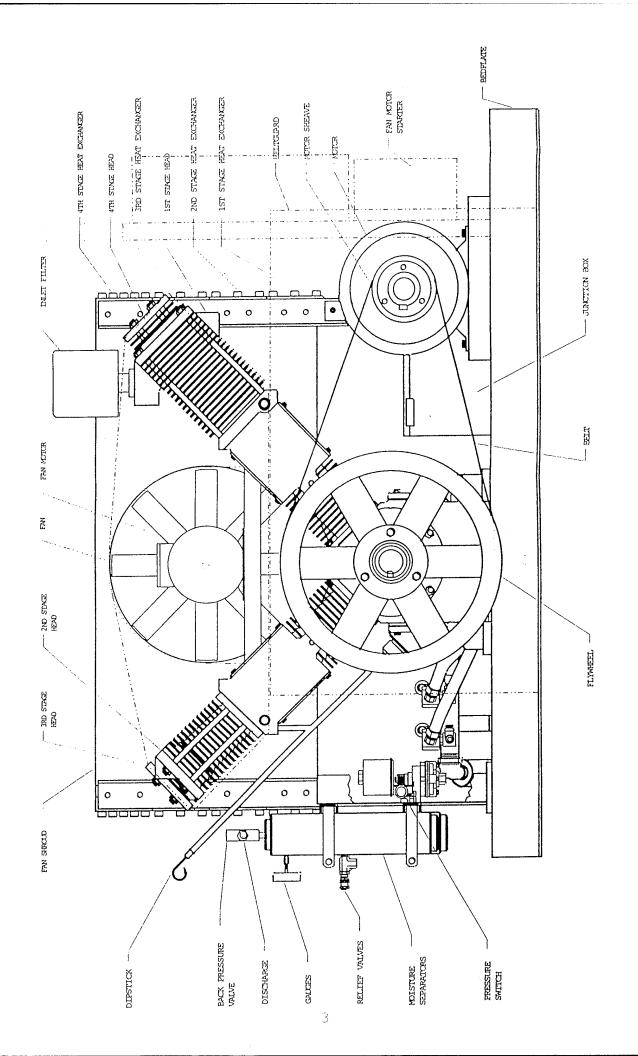
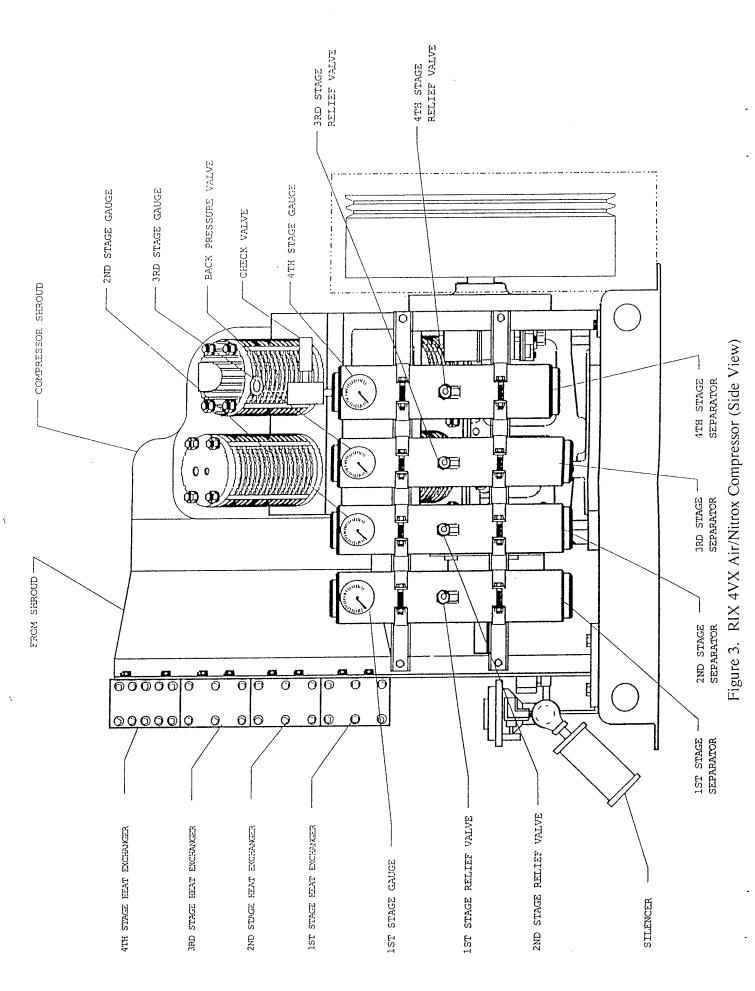


Figure 2. RIX 4VX Air/Nitrox Compressor (Rear View)



Built-in safety features automatically shut down the compressor if excessive temperatures or pressures are reached in the 4th stage discharge line. A pressure switch is connected to the 4th stage discharge downstream from the check valve. A temperature switch bulb is strapped to the 4th stage discharge line upstream of the 4th stage heat exchanger. A low oil pressure switch will shut down the compressor if the pressure drops below the set pressure. Oil, interstage, and discharge pressures are indicated by gauges.

III. TEST PROCEDURE

There are various methods of testing compressor capacities, stability, and reliability. For this compressor evaluation², NEDU chose to run two separate tests of 50 hours each: one using nitrogen to evaluate the unit as a nitrox compressor, and one using air to evaluate the unit as an air compressor.

A. NITROGEN TEST

The compressor and all ancillary equipment were received and set up as per manufacturer's instructions. Test setup is shown in Figure 4. A Cole Palmer Model 8502-14 temperature monitor and Yellow Springs Instruments 700 Series thermistor probes were attached for measuring compressor discharge and ambient temperatures.

At the beginning of each test day, the compressor and volume tank were purged using nitrogen. Once the system was fully charged, the nitrogen source was secured. The nitrogen was then circulated in a closed loop configuration (round-robin) for the duration of the test day. Gas samples were tested after 1, 25, and 50 hours of testing. Results are presented in Appendix B.

Appendix A shows the recorded data from the Test Log. The unit was operated in an exterior work area, open to ambient temperature and humidity. The testing included subjective evaluation of the system operation but did not include detailed mechanical review of the individual components of the system.

Example computations (standard cubic feet per minute (SCFM)) for the nitrogen test are shown below. A flow reading of 20 cfm at13 psig and 32°F were calculated as follows:

SCFM = (Flow Reading)
$$X \sqrt{\frac{Flow \quad psig + 14.7}{14.7}} X \sqrt{\frac{460 + 70}{460 + Flow \quad Temp} \circ_F} X \sqrt{\frac{28.975}{28}}$$

$$20 X \sqrt{\frac{13 + 14.7}{14.7}} X \sqrt{\frac{460 + 70}{460 + 32}} X \sqrt{\frac{28.975}{28}} = 28.9 \text{ scfm}$$

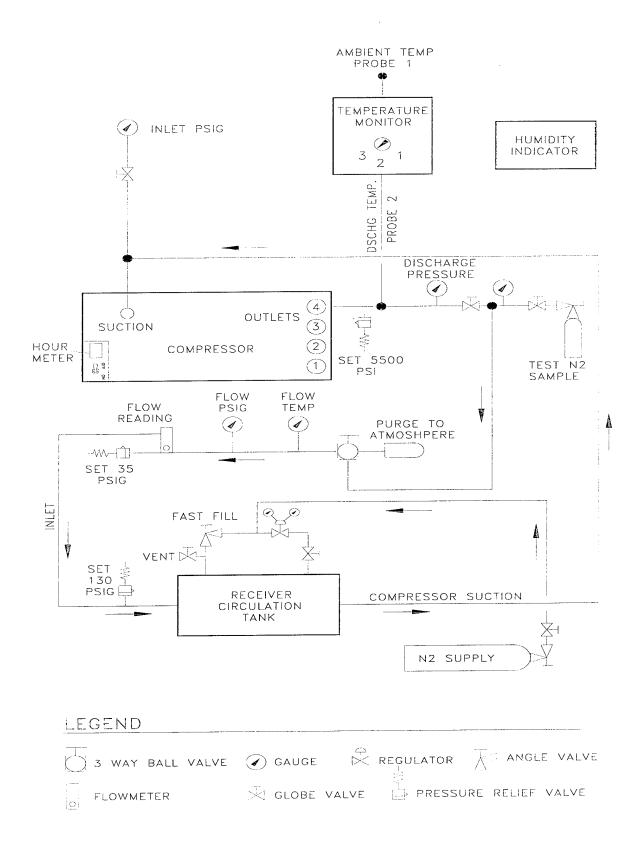


FIGURE 4. NEDU TEST NO. 95-14, NITROX CONFIGURATION

B. AIR TEST

The compressor and all ancillary equipment were set up as per manufacturer's instructions. Test setup is shown in Figure 5. A Cole Palmer Model 8502-14 temperature monitor and Yellow Springs Instruments 700 Series thermistor probes were attached for measuring compressor discharge, ambient temperatures, and storage cylinder air temperature.

The compressor was operated for extended periods charging an 89.2 liter (3.15 cuft) cylinder from 0 bars to 345 bars (0 to 5,000 psig). Total test time was 50 hours. Air samples were tested after 1, 25, and 50 hours of testing. Results presented in Appendix B.

Appendix A shows the recorded data from the Test Log. The unit was operated in an exterior work area, open to ambient temperature and humidity. The testing included subjective evaluation of the system operation but did not include detailed mechanical review of the individual components of the system.

Example computations for the air test are shown below.

A 3.15 cubic foot cylinder charged to 4725 psig in 29 minutes. The temperature at the beginning of the charge was 63.1 degrees F and was 120 degrees F when the 4725 psig was recorded.

The temperature correction factor was calculated as follows:

Temp. Corr. Factor =
$$\frac{T_1 + 460}{T_2 + 460} = \frac{63.1 + 460}{120 + 460} = \frac{523.1}{580.0} = .902$$

T₁ = Start Temperature °F

 T_2 = End Tempreature °F

The total volume (ATA X floodable volume) was calculated as follows:

Total Volume =
$$\frac{psig + 14.7}{14.7}$$
 x 3.15 ft.³ = $\frac{4725 + 14.7}{14.7}$ x 3.15 ft.³ = 1015.65 ft.³

Standard cubic feet per minute was calculated as follows:

$$\mathbf{SCFM} = \frac{Total \ Volume \ X \ Temperature \ Correction \ Factor}{Fill \ Time} = \frac{1015.65 \ X \ .902}{29 \ \text{min.}} = 31.6 \ \text{scfm}$$

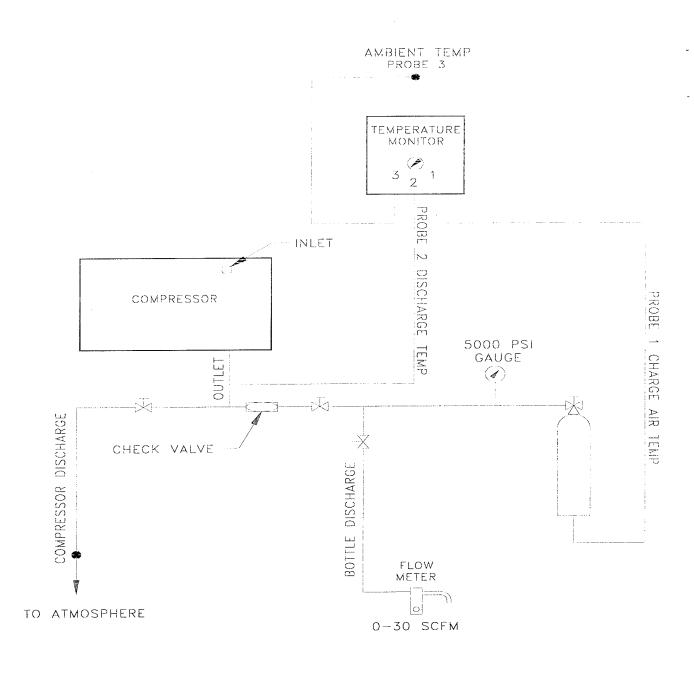




FIGURE 5. NEDU TEST NO. 95-14, AIR CONFIGURATION

IV. OBSERVATIONS/RECOMMENDATIONS

A. DELIVERY

Compressor capacity when using nitrogen was determined to be 818 liters per minute (28.9 SCFM) by calculating the average of the hourly flow rates recorded in Appendix A. Compressor capacity when using air was determined to be 848 liters per minute (30.0 SCFM) by calculating the average of the charging times recorded in Appendix A.

B. SAMPLING

Gas samples were taken from the compressor purification system discharge at the 1st, 25th, and 50th hour of running time. The samples were sent to the Coastal System Station (CSS) Laboratory, Code 5130, for purity analysis. Analysis of air samples (listed in Appendix B) show that the compressor meets U. S. Navy requirements.

C. OIL LUBRICATION

Because oil lubrication is only needed for the crankcase components, no oil consumption was expected. The crankcase oil level was checked at the beginning and end of each day's testing. The compressor did not consume or leak any oil during either test. The oil used during the testing was SAE 30 weight motor oil.

D. MAINTENANCE

No scheduled maintenance was required during this test. The following unscheduled maintenance was performed:

26 October 1022 Hour meter repaired.
 27 October 0920 Wire on electric power transformer repaired.
 30 October 0920 Wire on electric power transformer repaired. Relief valve replaced.

Some minor malfunctions were encountered during the evaluation. These malfunctions were the failure of the hour meter, fourth stage relief valve and the controller transformer. The manufacturer has been informed and has made component changes to eliminate the causes in future compressors.

V. CONCLUSIONS & RECOMMENDATIONS

A. The RIX Model 4VX air/nitrox compressor delivers air which exceeds the U.S. Navy standards³ for purity. The compressor output averaged 818 liters per minute (28.9 SCFM) of nitrox, or 849 liters per minute (30.0 SCFM) of air, per Appendix A. This exceeds the manufacturer's specification of 27 SCFM.

- B. The unit is sturdy, reliable, and readily maintained.
- C. Based on the results of testing, the RIX Model 4VX air/nitrox compressor system is recommended for inclusion on the Authorized for Navy Use List⁵.
- D. The vendor and NAVSEA should be contacted prior to purchase to ensure the unit meets the user's needs.

VI. REFERENCES

- 1. NAVSEA Task 95-18; <u>Evaluation of RIX 40X Air/Nitrox Compressor</u>. Naval Sea Systems Command, 1995
- 2. <u>RIX Model 4VX Air/Nitrox Compressor Evaluation Test Plan 93.33 (Unmanned)</u>, Navy Experimental Diving Unit, June 1995, Limited Distribution
- 3. NAVSEA 0994-LP-001-9010 <u>U.S. Navy Diving Manual</u>, Vol 1, Rev. 3, Para 5.3.2. Air purity standards, and 6.7.2.1. Air Compressors
- 4. Department of Defense MIL-M-17060 E Amendment 1, <u>Sealed Insulated Systems</u>, (Service A Use). Navy specification for compressor power source
- 5. Naval Sea Systems Command NAVSEAINST 10560.2C <u>Diving Equipment Authorized for U. S. Navy Use</u>

DATE: 25 October 25

													 	 	,	
		OIL	PSI		38	38	36	36	36	36	36	36				
		SCFM	(Calc)		28.99	28.59	28.75	29.15	29.01	28.23	29.27	29.27				
		FLOW	25		13	14	13	14	14	12	14	14				
		FLOW	2		20	19.5	20	20	20	20	20	20				
	·		4TH 5000		5000	2000	5000	4000	4000	5000	2000	2000				
	ESSOR	SI AGES	3RD 900-1100		1000	1000	1000	950	950	1000	1000	1000				
	COMPRESSOR	CTLINDER S	2ND 225-275		240	240	240	220	230	240	240	240				
			1ST 45-55		44	45	45	40	40	44	44	44				
		CYL	FILL TIME													
		INLET	MAX: 2.5 MIN: 0		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5				
	ER	TION	END													
	CYLINDER	INFORMATION	RT END IE TIME													
	Q		TEDSTA SI TIN					_								
	CHARGED	CYLINDER SIZE	RATEDRATEDSTART CU FT PSI TIME													
		AMBI	UMID %													
		FLOW	MAX: 70		32	38	40	44	49	40	40	40				
	TEMP°F	COMP	AMBI DSCHG PROBE #1 PROBE #2 IMAX: 70 MAX: 425 MIN: -10		45.5	46	53.8	64.3	63.1	55.2	53.2	52.6				
67		Ç	AMBI PROBE #1		79.7	81.9	84.9	86.1	86.1	86.2	85.4	86.9				
octobal		METER		Start	0/1	0/1	0/1	0/1	0/1	0/1	1/0	0/1				
CAILE: 23 OCTOBEL 23		TIME		0840	0940	1040	1140	1240	1340	1440	1540	1640				
	_	_	_						-		-			 		

NOTES: 1. Oil full at startup and shutdown,
2. Hourmeter inoperable on startup I/O. Manufacturer is shipping a new one.

NITROGEN TEST

DATE: 26 October 1995

						,		,	,					 	,
	OIL PRESS	PSI		38	36	36	36	36	36	36	36				
	SCFM	Calc		28.03	27.75	28.46	28.29	28.75	28.78	28.75	28.26			·	
	FLOW	200		12	12	12	12	13	13	13	12				
	FLOW	9		1.95	19.5	20	20	20	20	20	20				
		4TH 5000		2000	2000	2000	2000	5000	5000	5000	5000				
ESSOR	STAGES	3RD 900-1100		950	950	950	950	1000	1000	1000	1000				
COMPRESSOR	CYLINDER S	2ND 225-275		230	230	230	230	240	240	240	240				
		1ST 45-55		44	45	45	45	45	45	45	45				
	CYL	FILL											;		
	INLET	MAX: 2.5 MIN: 0													
CYLINDER	INFORMATION	END END TIME PSI													
CHARGED	CYLINDER SIZE	RATED RATED START CU FT PSI TIME													
	AMBI	HUMID %		09	9	57	57	63	62	63	90				
	FLOW			22	32	32	38	40	39	40	39				
TEMP°F	COMP	AMBI DSCHG PROBE #1 PROBE #2 MAX: 70 MAX: 425 MIN: -10		90.5	95.3	101.2	104.8	105.3	105.5	104.9	104.8				
		AMBI PROBE #1		74.9	74.9	81.0	89.4	87.8	88.4	88.9	87.9				
	METER		Start	0/1	0/1	4.	1.4	2.4	3.4	4.4	5.4				
	TIME		0730	0830	0830	1030	1130	1230	1330	1430	1530				Ė

NOTES:

Oil full at startup and shutdown.
 Hour meter was repaired at 1022. Meter was reading .4 upon installation.

Appendix A-2

4VX BREATHING AIR PACKAGE/230V ACCEPTANCE TEST DATA RIX COMPRESSOR

NITROGEN TEST

DATE: 27 October 1995

	OIL	PSI		38	36			38	36	36	36				
	SCFM	Calc		28.81	28.75			28.75	29.21	29.21	29.21				
	FLOW	200		13	13			13	14	14	14				
	FLOW	9		20	20			20	20	20	20				
		4TH 5000		5000	2000			5000	5000	5000	2000				
SSOR	_	3RD 900-1100		1000	1000	:		1000	1000	1000	1000				
COMPRESSOR CYLINDER STAGES	SG.	2ND 225-275		240	240			240	240	240	240				
		1ST 45-55		45	45			45	45	45	45				
	CYL	FILL TIME													
<u> </u>	PSIG	MAX: 2.5 MIN: 0		2.5	2.5			2.5	2.5	2.5	2.5				
R ER	NOIT	END													
CYLINDER	IFORMA	TEND E TIME											ļ 	 	
		EDSTAI													
CHARGED	SIZE	RATEDRATED START CU FT PSI TIME													
	AMBI			77	77			84	80	77	78	 			
	FLow ,	MAX: 70 H		38	40		, .	40	42	42	42				own.
TEMP°F	COMP	AMBI DSCHG PROBE #1 PROBE #2 MAX: 70 MAX: 425 MIN: -10		102.5	103.7			101.5	105.8	106.6	106.1				NOTES: 1 Oil full at startup and shutdown.
		AMBI PROBE #1		84.7	90.1			90.1	88.5	88.7	88.4				at startu
	METER	2	Start	6.4	7.4	Stop	Start	7.8	8.8	9.6	10.8				1 031 ft
	TIME		0700	0800	0060	0920	1126	1126	1226	1326	1446				NOTES:

On full at standards and should not stabilize discharge pressure to 5000 psi. Compressor began to clatter and pulsate struggling to keep running. Began troubleshooting. Operating vibration caused 2. hard copper wire on electric power transformer to break, disconnecting control's power source to programmable controller and causing complete shutdown of power.

3. Fourth stage relief valve began to fail, opening at 4800 psi. Made adjustment to continue test.

Appendix A-3

4VX BREATHING AIR PACKAGE/230V ACCEPTANCE TEST DATA RIX COMPRESSOR

NITROGEN TEST

DATE: 30 October 1995

																	 	,—
	OIL	PSI		42	39	36	37	37		36			37	36	36			
	SCFM	(Calc)		A N	ĄN	29.75	29.81	29.75		29.63			29.75	29.63	29.69	·		
	FLOW	7 910		14	14	14	14	14		14			14	14	14			
	FLOW	9		19.5	19.5	19.5	20	20		20			20	20	20			
		4TH 5000		4900	4900	4900	5000	5000		5000			2000	5000	5000			
ESSOR		3RD 900-1100		950	1000	1000	1000	1000		1000			1000	1000	1000			
COMPRESSOR CYLINDER STAGES	PSI	2ND 225-275		230	240	240	245	245		245			240	245	245			
		1ST 45-55		44	45	45	45	45		45			44	45	45			
	CYL	FILL																
	INLET	MAX: 2.5 MIN: 0		2.5	2.5	2.5	2.5	2.5		2.3			2.5	2.5	2.5			
E 5	NOIL	END																
CYLINDER	INFORMATION	TEND E TIME												-			 	
		ATED START PSI TIME																
CHARGED	CYLINDE	RATED RATED START CU FT PSI TIME																
		HUMID %		74	72	70	69	99		64			99	89	74			
	FLOW			ΑN	ΝΑ	ΑN	22	24		28			24	28	26			
TEMP°F	COMP	AMBI USCHG PROBE #1 PROBE #2 MAX: 70 MAX: 425 MIN: -10		NA	81.4	85.3	88.5	92.1		95.5			80.1	82	92.6			the property of the property o
				61.3	62.2	68.5	69.5	74.5		78.1			77.8	76.3	73.2			***************************************
	METER		Start	10.8	11.8	12.8	13.8	14.8	Sample	15.8	Stop	Start	15.9	16.9	17.9			-
	TIME		0110	0710	0810	0910	1010	1110	1115	1210	1220	1320	1320	1420	1520			NOTEO.

NOTES:

Oil full at startup and shutdown.
 Discharge pressure at 4900 psi at time of startup; 5500 psi fourth stage relief valve leaked over 4900 psi, causing loss of nitrogen to atmosphere. Replaced relief valve while down to repair transformer (1220).
 At 1218 compressor began to cut off and on rapidly as it did on 17 Oct. At 1220 compressor shut itself off. Problem was again a broken transformer wire due to constant vibration to power panel assembly, causing loss of power. Broken wire was on the same board as the previously broken wire. See recommendations section for operator's suggestion.

DATE: 1 November 1995

·		1			T	\neg	1					$\overline{}$					
	OIL PRESS	PSI	40	37	36	36	36	36			36	36	36	36	36	36	
	SCFM	(2002)	29.69	29.57	29.45	29.27	29.24	29.27			29.27	29.21	29.33	29.39	29.39	29.39	
	FLOW	5	14	14	14	14	14	14			14	14	14	14	14	14	
	FLOW	2	20	20	20	20	20	20			20	20	20	20	20	20	
		4TH 5000	4800	5000	5000	5000	5000	5000			5000	5000	5000	2000	5000	2000	
ESSOR	31	3RD 900-1100	950	1000	1000	1000	1000	1000			1000	1000	1000	1000	1000	1000	
COMPRESSOR	PSI	2ND 225-275	230	240	245	245	245	245			245	245	245	245	245	245	
		1ST 45-55	44	45	45	45	45	45			45	45	45	45	45	45	
	ζK	FILL															
	INLET PSIG	MAX: 2.5 MIN: 0	2.5	2.3	2.2	2.2	2.1	2.1			2.3	2.3	2.2	2.2	2.2	2.2	
e: 5	NOI	END															
CYLINDER	INFORMATION	T END TIME											-				
	Ž	DSTART															
CHARGED	CYLINDER SIZE	RATED START CU FT PSI TIME															 ,
	AMBI	HUMID %	66	91	98	79	80	80			80	80	91	93	93	94	
	FLOW		26	30	34	40	41	40			40	42	38	36	36	36	
TEMP°F	МОЭ	AMBI DSCHG PROBE #1 PROBE #2 MAX: 70 MAX: 425 MIN: -10	82.1	94.8	98.7	103.6	105.6	105.6				105.2	100.2	99.7	100.7	100.1	
		AMBI PROBE #1	72.5	76.7	80.6	85.8	88.3					86.4	83.3	81.8	83.0	82.7	
	METER		25.9	26.9	27.9	28.9	29.9	30.1	Stop	Start	30.1	31.1	32.1	33.1	34.1	35.5	
	TIME		0703	0803	0903	1003	1103	1120	1120	1256	1256	1356	1456	1556	1656	1725	

NOTES: 1. Oil full at startup and shutdown.

DATE: 31 October 1995

			TEMP°F			CHARGED	CYLINDER	œ º				COMPRESSOR	SSOR					
TIME	METER	Ç	COMP	FLOW	AMBI		€	NO.	INLET PSIG	CYL		CTLINDEN	o i Adeo		FLOW	FLOW	SCFM	OIL
	2	AMBI PROBE #1	AMBI DSCHG PROBE #1 PROBE #2 MAX; 70 MAX: 425 MIN: -10	MAX: 70 MIN: -10	HUMID %	RATED RATED START CU FT PSI TIME	DSTART END TIME TIME	END M.	MAX: 2.5 MIN: 0	FILL	1ST 45-55	2ND 225-275	3RD 900-1100	4TH 5000	200	2	Canc	PSI
0200	17.9	68.1	NA	NA	95				2.5		44	220	950	4500	20	14	Ą	44
0800	18.9	6.89	88.2	22	94				2.5		45	230	1000	5000	20	14	29.81	38
0060	19.9	70.5	6.68	24	91				2.2		45	245	1000	5000	19.5	14	29.00	36
1000	20.9	73.2	9.18	26	88				2.3		45	245	1000	5000	19.5	14	28.94	36
1100	21.9	73	93.3	28	88				2.2		45	245	1000	5000	19.5	14	28.89	36
1200	22.9	74.2	94.8	28	88				2.1		45	245	1000	5000	19.5	14	28.89	36
1300	23.9	78.9	98.0	32	79				2.0		45	245	1000	5000	19.5	14	28.77	36
1400	24.9	79.5	98.5	32	80				2.2		45	245	1000	5000	19.5	14	28.77	36
1500	25.9	77.4	98.5	32	81				2.2		45	245	1000	5000	19.5	14	28.77	36
									N.					,,				
NOTES:	1. Oil f	'ull at startı	1. Oil full at startup and shutdown.	tdown.														

DATE: 2 November 1995

									 	,	 	,		,	
OIL	PSI	40	36	36	36	36		36							
SCFM	(Calc)	29.69	28.71	28.59	28.48	28.42		28.42					-		
FLOW	25	14	14	14	14	14		14							
FLOW	Ž	20	19.5	19.5	19.5	19.5		19.5							
	4TH 5000	5000	5000	5000	5000	2000		5000							
COMPRESSOR CYLINDER STAGES PSI	3RD 900-1100	1000	1000	1000	1000	1000		1000							
COMPRES CYLINDER S PSI	2ND 225-275	240	245	245	245	245		245							
	1ST 45-55	44	45	45	45	45		45							
CYL	FILL														
INLET	MAX: 2.5 MIN: 0	2.3	2.5	2.3	2.3	2.3		2.3							
CYLINDER CHARGING INFORMATION	START END END TIME TIME PSI					,									
CHARGED CYLINDER SIZE	RATEDRATEDSTART CU FT PSI TIME														
AMBI	HUMID %	100	97	72	79	81		78							
FLOW	MAX: 70 MIN: -10	26	34	38	42	44		44							tdown.
TEMP°F	AMBI DSCHG PROBE #1 PROBE #2 MAX: 70 MAX: 425 MIN: -10	82.4	0.66	102.9	105.9	107.5		108.1							NOTES: 1. Oil full at startup and shutdown.
	AMBI PROBE #	72.8	82.6	84.2	86.4	90.6		92.2							ull at star
METER	2	34.5	35.5	36.5	37.5	38.5	Sample	39.0							1. Oil fu
TIME		0557	0657	0757	0857	0957	1004	1024							NOTES:

AIR TEST

DATE: 8 November 1995

S C S	(ago)	31.6									
	END PRESSURE	4725									
	END TEMPERATURE	120									
	START PRESSURE	0									
	START TEMPERATURE	63.1									
Š	FILL	29									
	DISCHARGE TEMPERATURE	42.1	43.0	49.3							
	4TH 5000	1850	1850	1850					* 1.		
	3RD 900-1100	850	850	850							
COMPRESSOR INFORMATION	2ND 225-275	240	240	240							
	1ST 45-55	45	45	45							
	OIL	41	38	38					i		
AMBIENT	ниміріту	64	59	99							
AMBIENT	темР.	65.3	67.2	70.1							
METER	ноияѕ	43.5	46.0	47.0							
	ω E	0858	0958	1058							

NOTES: 1. Oil full at startup and shutdown (oil pressure 44 psi on start up).

Appendix A-8

AIR TEST

DATE: 9 November 1995

(0)					\prod								
SCEM (Calc)			32.2			31.9		29.7					
	END PRESSURE		4800			4750		4775					
	END TEMPERATURE		105.8			115.5		120.7					
	START PRESSURE		200			500		0					
	START TEMPERATURE		41.7			42.5		44.8					
>	FILL		25.5			25.0		30					
	DISCHARGE TEMPERATURE	25.1	32.4	38.3	40.7	44.5	49.9	50.9	48.6				
	4TH 5000	1850	1850	1850	1850	1850	1850	4250	1850				
	3RD 900-1100	850	850	850	850	850	850	1000	850				
COMPRESSOR INFORMATION	2ND 225-275	230	240	240	240	240	240	240	240				
	1ST 45-55	45	45	45	45	45	45	45	45				
	OIL PRESSURE	50	42	40	38	36	36	36	36				
AMBIENT	HUMIDITY	99	64	63	09	57	54	52	50				-
	темР.	48.4	51.2	55.3	50.9	64.5	67.3	70.9	70.9				
	HOURS	47.6	48.6	49.6	50.6	51.6	52.6	54.8	56.0				
	IIME	0020	0800	0060	1000	1100	1200	1416	1523				

NOTES: 1. Oil full at startup and shutdown (start oil pressure @ 50 psi).
2. End temperature was taken on all readings 15 minutes after stop charging.

AIR TEST

DATE: 13 November 1995

-	, 	П	T	\neg	T							
SOFM Calci		31.3				30.7						
	END PRESSURE	4725				4650						
	END TEMPERATURE	110.6				123.3		-				
	START PRESSURE	0				0						
	START TEMPERATURE	50				64.2						
5	FILL	29				29.3						
	DISCHARGE TEMPERATURE	31.3	37.8	39.5	43.3	51.2	51.8					
	4TH 5000	3800	1850	1850	1850	4500	1850					
	3RD 900-1100	1000	850	850	850	1000	850					
COMPRESSOR	2ND 225-275	240	240	240	240	245	240					
	1ST 45-55	45	45	45	45	45	45					
	OIL PRESSURE	40	39	39	38	38	36					
	HUMIDITY	52	47	42	40	43	45					
AMBIENT	TEMP.	54.9	57.1	60.1	63.4	73.9	70.9					
	HOURS	56.4	57.5	58.5	59.5	61.3	62.3					
	Ε Ε Ε	0070	0800	0905	1005	1340	1440					

NOTES: 1. Oil full at startup and shutdown (start up oil pressure @ 48 psi).

Appendix A-10

AIR TEST

DATE: 21 November 1995

1	METER					COMPRESSOR INFORMATION				2					SCEM (Cate)
я Б П	HOURS	темр.	HUMIDITY	OIL	1ST 45-55	2ND 225-275	3RD 900-1100	4TH 5000	DISCHARGE TEMPERATURE	FILL	START TEMPERATURE	START PRESSURE	END TEMPERATURE	END PRESSURE	
0020	63.0	61.7	82	39	45	240	850	1850	37.2						
0800	64.0	72.8	54	38	46	245	1000	5000	54.3	22	80.1	1000	123.5	4750	33.9
0060	65.0	70.0	55	36	45	240	850	1850	49.1						
1028	66.4	75.4	52	36	46	245	1000	5000	51.3	29.5	42.6	0	115.0	4750	30.1
1128	67.4	76.9	51	36	45	240	850	1850							
1233	68.5	77.6	48	36	46	245	1000	2000	60.9	27.5	41.2	250	116.2	4675	30.1
1333	69.5	78.9	46	36	45	240	058	1850	61.0						
1442	70.6	80.4	46	36	46	245	1000	0009	59.4	31.4	44.3	0	126.0	4800	28.3
NOTES.	1 10	Il as estartion	1 Oil full at etastim and chartdown												

NOTES: 1. Oil full at startup and shutdown. 2. At 0928 OL light came on and compressor shut down. Pressed reset and restarted.

Appendix A-11

AIR TEST

DATE: 22 November 1995

								 	 r —	 	 _	T
I STOCK WILL CO	OCTIVI (CAIC)	29.1		29.2		28.7	31.3					Again pressed ton light 2 went pply to machine
	END PRESSURE	4000		4100		4900	4900					nut down again. ushing reset but stable power su
	END TEMPERATURE	110.2		109.6		126.0	120.3					6 minutes and sl
	START PRESSURE	0		500		,0	850					n approximately , 2, 3,6, and 7 w
	START TEMPERATURE	47.8		44.6		44.1	47.4					Compressor ra before resetting
5	FILL	26.4		23.5		31.6	24.4					ted compressor. roller cover and, Nir temperature e
	DISCHARGE TEMPERATURE	4250	40.1	52.2	44.3	48.0	60.4					 Oil full at startup and shutdown. Suring charge compressor shut down when OL light came on; stopped charge and took first reading. Pressed reset and restarted compressor. Compressor ran approximately 6 minutes and again OL light came on and compressor shut down. Removed controller cover and, before resetting, 2, 3,6, and 7 were lit. When pushing reset button light 2 went rest compressor shutdown for fourth time. Cause unknown. Air temperature and oil pressure normal. Only possible cause; unstable power supply to machine.
	4TH 5000	4250	1850	4300	1850	2000	2000					t reading. Pres pressor shut do for fourth time
	3RD 900-1100	1000	850	1000	850	1000	1000					rge and took firs ame on and com essor shutdown
COMPRESSOR	2ND 225-275	245	240	245	240	245	245					on; stopped cha again OL light ca charding, compr
	1ST 45-55	46	45	45	45	46	46					OL light came 35 minutes and tes later, while
	OIL	40	40	40	40	38	38					wn. hut down when ior. It ran for S
	HUMIDITY	55	45	42	42	42	42					Oil full at startup and shutdown. During charge compressor shut reset and restarted compressor off and compressor started again.
AMBIENT	TEMP.	51.4	58.4	61.0	66.8	70.3	68					ull at startuping charge or and restart nd compres
METER	HOURS	72.3	73.5	74.0	75.1	76.7	78.3					2.1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		0730	9060	1016	1128	1303	1439					NOTES:

or controller failure.

4VX BREATHING AIR PACKAGE/230V ACCEPTANCE TEST DATA RIX COMPRESSOR

AIR TEST

DATE: 24 November 1995

SCFM (Calc)	END PRESSURE	4800 29.4			4750 28.6			-				
	END EN TEMPERATURE PRES	111.3 48			116.1 47							
	START PRESSURE	0			0		***************************************					
	START TEMPERATURE	46.6			47.2							
2	TIME	31.2			31.5							
	DISCHARGE TEMPERATURE	49.9	47.5	41.9	40.2	37.4						
	4TH 5000	.0009	1850	1850	5000	1850						
<i>m</i> 7	3RD 900-1100	1000	850	850	1000	850						
COMPRESSOR	2ND 225-275	245	240	240	245	240						
	1ST 45-55	46	45	45	46	45						
	OIL	39	39	39	39	39						
AMBIENT	HUMIDITY	95	96	97	86	96						NOTES: 1 Oil full at startup and shutdown.
AMBIENT	TEMP.	65.1	66.4	64.9	62.7	63.3						at startin
	HOURS	79.8	80.5	81.5	82.9	83.9						
	Σ Σ	0230	0833	0933	1109	1209						NOTES:

Oil full at startup and shutdown.
 Compressor had run 1 hour, 11 minutes when OL light came on and compressor shut down. Pressed reset, restarteed. Compressor shut down again at 0908; pressed reset, restarted.

AIR TEST

DATE: 27 November 1995

		- 1			·······					т		1	 	 г
OF CO		29.5			28.8			28.4			28.0			
	END PRESSURE	4725			4675			4550			3450			
	END TEMPERATURE	121.5			115.8			112.3			112.2			
	START PRESSURE	0			0			0			500			
	START TEMPERATURE	54.8			45			46.9			44.1			
5	FILL	30.5			30.6			30.5			20			
	DISCHARGE TEMPERATURE	58.3	52.3	56.4	58.3	59.9	60.3	61.3	60.3	60.2	59.3			
	4TH 5000	5000	1850	1850	5000	1850	1850	5000	1850	1850	3400			
	3RD 900-1100	1000	850	850	1000	850	850	1000	850	850	98			
COMPRESSOR	2ND 225-275	245	240	240	245	240	240	245	240	240	245			
	1ST 45-55	46	45	45	46	45	45	46	45	45	46			
	OIL	38	38	38	38	36	36	36	36	36	36			
	HUMIDITY	78	78	67	99	63	68	99	70	76	62			
AMBIENT	TEMP.	70	70	77.5	80.2	80.9	83	83	82	84	81			
	HOURS	85.1	86.1	87.1	88.0	98.0	90.0	90.7	91.7	92.7	93.0			
F S	1 - -	0722	0822	0922	1014	1114	1214	1254	1454	1455	1515			

NOTES: 1. Oil full at startup and shutdown.

Appendix A-14

To: Dave Sullivan, NEDU

From: Glen Deason, Code 2530

Subject: Analysis of air sample from RIX Model 4VX Compressor, Test plan 95-14. 1-Hour sample.

1. In accordance with your request, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Standard Components

Component	Level	Limit
0xygen	TIMO	20-2282
Nitrogen	100.0%	NONE ²
Argon	TIMO	NONE ²
Carbon Dioxide	OMIT	1000 PPM ²
Total Hydrocarbons ¹	<0.5 PPM	25 PPM ²
Carbon Monoxide	<0.5 PPM	20 PPM ²
Methane	<0.1 PPM	1000 PPM ²
Acetone	<0.1 PPM	200 PPM ²
Benzene	<0.1 PPM	1 PPM ²
Chloroform	<0.1 PPM	1 PPM ²
Ethanol	<0.1 PPM	100 PPM ²
Freon 113	<0.1 PPM	100 PPM ²
Freon 11	<0.1 PPM	100 PPM ²
Freon 12	<0.1 PPM	100 PPM ²
Freon 114	<0.1 PPM	100 PPM ²
Isopropyl Alcohol	<0.1 PPM	1 PPM ²
Methanol	<0.1 PPM	10 PPM ²
Methyl Chloroform	<0.1 PPM	30 PPM ²
Methyl Ethyl Ketone	<0.1 PPM	20 PPM ²
Methyl Isobutyl Ketone	<0.1 PPM	20 PPM ²
Methylene Chloride	<0.1 PPM	25 PPM ²
Toluene	<0.1 PPM	20 PPM ²
Trimethyl Benzenes	<0.1 PPM	3 PPM ²
Xylenes	<0.1 PPM	50 PPM ²

Other Components

Component Level LIMTS

NONE

C4+ <0.1 PPM NONE

¹Expressed as methane equivalents.

²Limits taken from Navy Dive Manual; Vol. 2, Rev. 3.

³OSHA Final Rule limits published as of July 1992 (not specified in Navy Dive Manual).

2. The above sample showed no appreciable contamination; all components were within the acceptable range.

Glen Deason Chemist To: Dave Sullivan, NEDU

From: Glen Deason, Code 2530

Subject: Analysis of air sample from RIX Model 4VX Compressor, Test plan 95-14. 25-Hour sample.

In accordance with your request, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Standard Components

dard Components		مسائل ويسا
	Level	Limit
Oxygen Nitrogen Argen Carbon Dioxide Total Hydrocarbons' Carbon Monoxide Methane Acetone Benzene Chloroform Ethanol Freon 113 Freon 11 Freon 12 Freon 114 Isopropyl Alcohol Methyl Chloroform Methyl Ethyl Ketone Methyl Isobutyl Ketone Methyl Isobutyl Ketone Methylene Chloride Töluene Trimethyl Benzenes Xylenes	OMIT 100.0% OMIT OMIT OMIT <0.5 PPM <0.5 PPM <0.1 PPM	20-22% ² NONE ² NONE ² 1000 PPM ² 25 PPM ² 20 PPM ² 1000 PPM ² 1 PPM ² 1 PPM ² 100 PPM ² 20 PPM ² 25 PPM ² 20 PPM ² 3 PPM ² 50 PPM ²
Component	Level	LIMTS
COMPOSTOR -		

other

1 11		LIMTS
	Level	LIMIO
Component	TEACT	
Combonenc		

NONE

NONE <0.1 PPM C4+

¹Expressed as methane equivalents.

²Limits taken from Navy Dive Manual; Vol. 2, Rev. 3.

³OSHA Final Rule limits published as of July 1992 (not specified in Navy Dive Manual).

2. The above sample showed no appreciable contamination; all components were within the acceptable range.

Glen Deason Chemist

Appendix B-4

To: Dave Sullivan, NEDU

From: Glen Deason, Code 2530

Subject: Analysis of air sample from Rix Model 4VX Compressor

Test. Plan 95-14, 50 Hour Sample.

1. In accordance with your request, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Standard Components

Component	Level	Limit
Oxygen	TIMO	20-22%2
Nitrogen	100.0%	NONE ²
Argon	OMIT	NONE ²
Carbon Dioxide	TIMO	1000 PPM ²
Total Hydrocarbons 1	<0.5 PPM	25 PPM ²
Carbon Monoxide	<0.5 PPM	20 PPM ²
Methane	<0.1 PPM	1000 PPM ²
Acstone	<0.1 PPM	200 PPM ²
Benzene	<0.1 PPM	1 PPM ²
Chloroform	<0.1 PPM	1 PPM ²
Ethanol	<0.1 PPM	100 PPM ²
Freon 113	<0.1 PPM	100 PPM ²
Freon 11	<0.1 PPM	100 PPM ²
Freon 12	<0.1 PPM	100 PPM ²
Freon 114	<0.1 PPM	100 PPM ²
Isopropyl Alcohol	<0.1 PPM	1 PPM ²
Methanol	<0.1 PPM	10 PPM ²
Methyl Chloroform	<0.1 PPM	30 PPM ²
Methyl Ethyl Ketone	<0.1 PPM	20 PPM ²
Methyl Isobutyl Ketone	<0.1 PPM	20 PPM ²
Methylene Chloride	<0.1 PPM	25 PPM ²
Toluene	<0.1 PPM	20 PPM²
Trimethyl Benzenes	<0.1 PPM	3 PPM ²
Xylenes	<0.1 PPM	50 PPM ²

Other Components

Component Level LIMTS

NOME

C4+ <0.1 PPM NONE

¹Expressed as methane equivalents.

²Limits taken from Navy Dive Manual; Vol. 2, Rev. 3.

³OSHA Final Rule limits published as of July 1992 (not specified in Navy Dive Manual).

2. The above sample showed no appreciable contamination; all components were within the acceptable range.

Glen Deason Chemist To: Dave Sullivan, NEDU

From: Glen Deason, Code 2530

Subject: Analysis of air sample from Rix Model 4VX Compressor

Test. Plan 95-14, 1 Hour Sample. AM TEST

1. In accordance with your request, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Standard Components

Component	Level	Limit
Oxygen	21.0%	20-22%2
Nitrogen	78.1%	NONE ²
Argon	0.9%	NONE ²
Carbon Dioxide	210 PPM	1000 PPM ²
Total Hydrocarbons ¹	3.7 PPM	25 PPM ²
Carbon Monoxide	<0.5 PPM	20 PPM ²
Methane	3.7 PPM	1000 PPM ²
Acetone	<0.1 PPM	200 PPM ²
Benzene	<0.1 PPM	1 PPM ²
Chloroform	<0.1 PPM	1 PPM ²
Ethanol	<0.1 PPM	100 PPM ²
Freon 113	<0.1 PPM	100 PPM ²
Freon 11	<0.1 PPM	100 PPM ²
Frecn 12	<0.1 PPM	100 PPM ²
Freon 114	<0.1 PPM	100 PPM ²
Isopropyl Alcohol	<0.1 PPM	1 PPM ²
Methanol	<0.1 PPM	10 PPM ²
Methyl Chloroform	<0.1 PPM	30 PPM^2
Methyl Ethyl Ketone	<0.1 PPM	20 PPM ²
Methyl Isobutyl Ketone	<0.1 PPM	20 PPM ²
Methylene Chloride	<0.1 PPM	25 PPM ²
Toluene	<0.1 PPM	20 PPM ²
Trimethyl Benzenes	<0.1 PPM	3 PPM ²
Xylenes	<0.1 PPM	50 PPM^2

Other Components

Component Level LIMTS

NOME

C4+ <0.1 PPM NONE

Appendix B-7

¹Expressed as methane equivalents.

²Limits taken from Navy Dive Manual; Vol. 2, Rev. 3.

³OSHA Final Rule limits published as of July 1992 (not specified in Navy Dive Manual).

2. The above sample showed no appreciable contamination; all components were within the acceptable range.

Glen Deason Chemist To: Dave Sullivan, NEDU

From: Glen Deason, Code 2530

Subject: Analysis of air sample taken from RIX Model 4VX Compressor Test. 95-14 Air Test, 25 Hour Sample.

 In accordance with your request, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Standard Components

Component	Level	Limit
Oxygen	21.0%	20-22%2
Nitrogen	78.1%	NONE ²
Argon	0.9%	NONE ²
Carbon Dioxide	296 PPM	1000 PPM ²
Total Hydrocarbons ¹	3.4 PPM	25 PPM ²
Carbon Monoxide	<0.5 PPM	20 PPM ²
Methane	3.4 PPM	1000 PPM ²
Acetone	<0.1 PPM	200 PPM ²
Benzene	<0.1 PPM	1 PPM ²
Chloroform	<0.1 PPM	1 PPM ²
Ethanol	<0.1 PPM	100 PPM ²
Freon 113	<0.1 PPM	100 PPM ²
Freon 11	<0.1 PPM	100 PPM ²
Freon 12	<0.1 PPM	100 PPM ²
Freon 114	<0.1 PPM	100 PPM ²
Isopropyl Alcohol	<0.1 PPM	1 PPM ²
Methanol	<0.1 PPM	10 PPM ²
Methyl Chloroform	<0.1 PPM	30 PPM ²
Methyl Ethyl Ketone	<0.1 PPM	20 PPM ²
Methyl Isobutyl Ketone	<0.1 PPM	20 PPM ²
Methylene Chloride	<0.1 PPM	25 PPM ²
Toluene	<0.1 PPM	20 PPM ²
Trimethyl Benzenes	<0.1 PPM	3 PPM ²
Xylenes	<0.1 PPM	50 PPM ²

Other Components

Component Level LIMTS

NONE

¹Expressed as methane equivalents.

²Limits taken from Navy Dive Manual; Vol. 2, Rev. 3.

³OSHA Final Rule limits published as of July 1992 (not specified in Navy Dive Manual).

2. The above sample showed no appreciable contamination; all components were within the acceptable range.

Glen Deason Chemist To: Dave Sullivan, NEDU

From: Glen Deason, Code 2530

Subject: Analysis of air sample taken from RIX Model 4VX Compressor Test. 95-14 Air Test, 50 Hour Sample.

 In accordance with your request, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Standard Components

Component	Level	Limit
Oxygen	21.0%	20-22%2
Nitrogen	78.1%	NONE ²
Argon	0.9%	NONE ²
Carbon Dioxide	345 PPM	1000 PPM ²
Total Hydrocarbons ⁱ	2.7 PPM	25 PPM ²
Carbon Monoxide	<0.5 PPM	20 PPM ²
Methane	2.7 PPM	1000 PPM ²
Acetone	<0.1 PPM	200 PPM ²
Benzene	<0.1 PPM	1 PPM ²
Chloroform	<0.1 PPM	1 PPM ²
Ethanol	<0.1 PPM	100 PPM ²
Freon 113	<0.1 PPM	100 PPM ²
Freon 11	<0.1 PPM	100 PPM ²
Freon 12	<0.1 PPM	100 PPM ²
Freon 114	<0.1 PPM	100 PPM ²
Isopropyl Alcohol	<0.1 PPM	1 PPM ²
Methanol	<0.1 PPM	10 PPM ²
Methyl Chloroform	<0.1 PPM	30 PPM ²
Methyl Ethyl Ketone	<0.1 PPM	20 PPM ²
Methyl Isobutyl Ketone	<0.1 PPM	20 PPM ²
Methylene Chloride	<0.1 PPM	25 PPM ²
Toluene	<0.1 PPM	20 PPM^2
Trimethyl Benzenes	<0.1 PPM	3 PPM ²
Xylenes	<0.1 PPM	50 PPM ²

Other Components

Component Level LIMTS

NONE

¹Expressed as methane equivalents.

²Limits taken from Navy Dive Manual; Vol. 2, Rev. 3.

³OSHA Final Rule limits published as of July 1992 (not specified in Navy Dive Manual).

2. The above sample showed no appreciable contamination; all components were within the acceptable range.

Glen Deason Chemist